Grain Structure and Residual Stress in Polycrystalline Metallic Films

J. Leib, C.V. Thompson
Sponsorship: NSF

In thin metal films deposited for various applications, there are obvious advantages to both understanding and controlling the intrinsic stresses in the films as-deposited. For high-mobility metal films (e.g., Au, Ag, Al, Cu) deposited on amorphous substrates, much of the observed stress can be attributed to the grain structure that evolves as the Volmer-Weber film transitions from individual islands to a continuous film. The stress behavior during this process shifts from tensile (during island coalescence) to compressive (as the film grows past continuity). Initially, the grain size of the continuous film is equal to the island size at coalescence.

The role of grain boundaries in the post-coalescence compressive stress has been debated extensively in the literature [1-4], but no experimental research has been performed to quantify the relationship between grain size and stress in polycrystalline films. In-situ stress monitoring and transmission electron microscopy (TEM) have been used to investigate stress and grain size in gold films deposited on silicon nitride. When films were treated to different grain sizes, stress-measured, and then imaged in TEM, the inverse of grain size and corresponding tensile rise was found to be linear, with zero stress at infinite grain size. This relationship indicates that grain boundaries are critical to the formation of compressive stress in these films, with the stress proportional to the grain boundary perimeter line length per area of film (see Figure 1).

While this result supports a model for compressive stress arising from trapping of an excess population of self-interstitials at grain boundaries (as in reference [3]), the expected relaxation of these defects would be their diffusion back to the surface and attachment to surface steps. However, the thermal activation for grain boundary diffusion (~0.6 eV) was not observed in the corresponding stress relaxation (see Figure 2). Current investigations focus on identification of mechanisms consistent with the observed small activation energy (~0.1 eV).

References